III. *On a Freshwater Schizopod from Tasmania.* *By* George M. Thomson, *F.L.S.*

Read 2nd November, 1893.

(Plates XXIV.–XXVI.)

In a paper read before the Royal Society of Tasmania on November 14th, 1892, I have given a brief account of the discovery of this interesting Crustacean, *Anaspides tasmaniæ**, and have described it as the type, not only of a new genus, but of a new family of Schizopoda. In some respects, indeed, the structure of this animal is so unique as to entitle it to even higher specific rank; but in many of its characters it is found to be allied, though somewhat remotely, to the *Euphausiidæ* of Sars (*Thysanopodidæ* of Bronn's 'Thierreich'). Owing to long isolation it has undergone very profound modification.

I found this species in a pool near the summit of Mt. Wellington, Tasmania—that is, at a height of over 4000 feet. The pool was in a small crevice only two or three feet deep, but seemed to have somewhat extensive ramifications among the rocky masses of which the upper part of the mountain is composed. The shrimps which came into the more open part were mostly small; the larger ones appeared to hide in the deeper crevices of the pool and would not come out while anyone was near.

I obtained only a few specimens at the time of my visit (January, 1892), but Mr. L. Rodway, of Hobart, was kind enough to make an expedition to the top of the mountain at my request on May 24th, and obtained a further supply from under the thick coat of ice which then covered the pool. He secured them by setting a small baited muslin net, but found the larger specimens very shy, as they tried to get the bait through the meshes of the net without venturing inside. Still he was enabled to obtain both males and females, the former of which were not included in my own collection. Unfortunately, none of the specimens in my possession are well preserved, so that it has been very difficult to make out their anatomical structure, and impossible to arrive at several important details.

In the pools and swampy ground round the spot where these were taken, Mr. Rodway, and subsequently Mr. Morton, F.L.S., of Hobart, obtained specimens of a small Amphipod which I have described in the paper referred to as *Niphargus montanus.* This species, like *Anaspides,* is evidently a very old type, belonging, apparently, to a genus hitherto described only from Europe and composed chiefly of underground

* This form was originally described by me under the name of *Anaspis,* but as my friend the Rev. T. R. R. Stebbing informs me that this name is pre-occupied, I have altered it to *Anaspides,* at his suggestion, so that the name of the new order may not have to be changed.

species. Among these was also found a single specimen of *Phreatoicus australis*, Chilton, previously only obtained from water springs and marshy ground on Mt. Kosciusko in New South Wales at a height of 5700 feet. The type species, *P. typicus*, Chilton, is eyeless, and occurs in the subterranean waters of Canterbury, New Zealand. The genus *Phreatoicus*, as Dr. Chilton has shown *, is an archaic one; it is, indeed, a remarkably generalized form of Isopod.

I have given the new shrimp the following systematic position in the above paper, the name *Anaspides* being suggested by the total absence of carapace.

Tribe *SCHIZOPODA*.

Family ANASPIDÆ.

Carapace wanting; the cephalon and all the segments of the body distinct. Maxillipeds and succeeding seven pairs of limbs uniform in general structure, adapted for walking, furnished with external lamellar branchiæ. No egg-pouch (?). Pleopoda with well-developed natatory exopodites; endopodites of first and second pleopoda specially modified in the males as copulatory appendages. Uropoda normal. Auditory organ in the base of first pair of antennæ †. Development?

Genus Anaspides.

Anaspis, mihi, Trans. Roy. Soc. of Tasmania for 1892, p. 51.

Integument thin and flexible. Whole body divided into 15 distinct (subequal) segments, viz. one cephalic, eight thoracic, and six abdominal. Eyes well developed. First antennæ with 3-jointed peduncle and two flagella; second antennæ with well-developed scale on the second joint. Mandibles with 3-jointed palps. First maxillæ 2-branched; second pair 4-branched. Maxillipeds pediform, with two rudimentary branchiæ projecting externally from the coxa; exopodite small and rudimentary. Legs generally uniform in structure, 7- or 8-jointed, each furnished with a claw-like dactylos. The coxa of each leg (except those of the last pair) bears two external lamellar branchiæ which project forward, and the basos bears a well-developed natatory exopodite. Pleopoda with a rudimentary endopodite in the females and in the 3rd–5th pairs in the males. First pair in the males with the endopodite developed into a lamelliform organ (penis?); second pair with the same organ produced into a clasping-process. Telson short, rounded. Uropoda with both plates subequal; inner with a slight longitudinal median ridge; outer with an imperfect transverse articulation near the middle.

External Form.

The most remarkable and characteristic features of the body (Pl. XXIV. fig. 1) are (1) its separation into 15 distinct segments without any trace of a carapace, thus recalling

* "On a new and peculiar Freshwater Isopod from Mount Kosciusko," by Chas. Chilton, M.A., D.Sc. Records of the Australian Museum, vol. i. no. 8, p. 149.

† This character is not in the original diagnosis.

the appearance of an Amphipod, and (2) the external lamellate branchiæ of the thoracic appendages.

The cephalic segment is short and is produced into a triangular subacute rostrum (Pl. XXIV. fig. 2); the front margin, which is slightly hollowed out for the eye-sockets, is entire and rounded; the sides are not produced far downward, but leave the tumid basal joint of the mandibles exposed.

The eight thoracic and the six abdominal somites are distinctly articulated one to another, but there is much room for overlapping between them, so that a considerable power of flexion on the dorsal line is provided. In many specimens the posterior margin has its overlapping portion distinctly marked out from the rest of the segment by its much paler colour.

The first thoracic segment is only about half as long as the cephalon; its lateral portion, which extends further down than the sides of the preceding segment, is separated off by an oblique line into a distinct epimeron, which is widest anteriorly. The other thoracic segments are rather short, so that the thorax and cephalon together only equal in length the whole of the abdominal portion. The sides of all the segments are rounded and do not extend far down; there is no trace of epimeral marking, but the margins are thicker and more strongly chitinized than the remainder of the segment. Viewed externally, the lateral margins of the thoracic segments are nearly hidden by the branchiæ, which project almost to the bases of the second antennæ, and by the plumose exopodites of the 2nd to 6th pairs of peræopoda, which are produced upward and backward on the sides of the body.

The *colour* of these animals is a brownish grey, approximating closely to the sides and bottom of the pool in which they were found. The *integument* is very thin and somewhat tough, thinner indeed than that of any other free-swimming Crustacean with which I am acquainted. This is no doubt due in part to the semi-subterranean abode in which the animals occur. The external layer of the integument is transparent, and underneath it are cells containing the pigment to which the colour is due. There is no calcareous matter in the integument, neither nitric nor glacial acetic acid producing any trace of effervescence, or indeed appearing to alter it in any way. Strong nitric acid alters the pigment to a yellowish colour and rapidly dissolves it. The pigment-cells are somewhat hexagonal in form, and can be removed in a thin layer, presenting a tesselated appearance.

Appendages.

The *eye-peduncles* are short and stout, and are directed obliquely outward; they reach beyond the extremity of the basal joint of the second antennæ, but not so far as the extremity of the basal joint of the first pair. Each peduncle is 1-jointed, cylindrical in form, and very slightly enlarged toward the extremity; its length is about twice its diameter. The ocelli, which are very numerous, occupy about the upper third of the stalk; just below them, particularly on the outer side of the peduncle, are a very few short stiff hairs.

Anterior antennæ (Pl. XXIV figs. 3 and 4).—These organs are normally formed. The peduncle is 3-jointed, with the joints broad and somewhat flattened; the first and second joints are subequal in length, the basal slightly the largest and widest, and having a longitudinal suture tending somewhat obliquely outward along its upper surface; the second joint also bears a slight longitudinal groove on its upper surface, and is fringed on its outer margin with plumose setæ. The third joint, which is also similarly fringed on its outer margin, is broader at its distal than its proximal end, and carries two whip-like flagella. The outer flagellum is from two-thirds to three-fourths the length of the body, and is divided into very numerous articulations. In the youngest specimen examined, the body of which was only about 9 mm. long, there were 36 articulations on the outer and only 8 on the inner flagellum; but in adult specimens the number varies from 70 up to 92, which was the largest number observed. The articulations are furnished with a few short spinose setæ on both sides. On the ten or twelve joints nearest the peduncle the setæ are long and plumose, but they tend to become shorter and more simple on the joints nearer the extremity. On all the joints but those few setose ones nearest the peduncle there are blunt hairs or cilia of a very characteristic appearance, which are probably sensory organs.

The inner flagellum is about one-fourth the length of the outer, and usually consists of about one-fourth the number of articulations; the joints nearest the base have more or less plumose setæ, those further out have the setæ simple. But in the male this inner flagellum is modified in a curious manner (Pl. XXVI. fig. 12). The fifth and sixth joints are much dilated; the former bears a large tuft of slightly plumose setæ, while the latter carries two large stout setæ, which are rugose in their distal half; each is also apparently furnished with a nerve-fibre. The first seven joints also bear a number of short, curved, finger-like setæ, all more or less covered with rugosities, so as to resemble a round rasp or file; these rugosities are arranged in an annular manner and appear to consist of minute stiff hairs. These thickened processes are scattered somewhat irregularly, there being a tuft of about six or seven on the basal joint, then isolated ones or in twos or threes on the succeeding joints, about seven on the sixth joint, and three on the seventh; they are directed toward the upper surface of the flagellum, while the long setæ of the proximal joints are all on the lower surface. The remaining joints are simple, and carry short simple setæ as in the corresponding organ in the female. These peculiar processes in the male are probably sensory in their function; they certainly form a very distinct sexual modification.

The auditory cavity is placed in the basal joint of the peduncle of the first antennæ, its roof being formed by the flattened upper surface. It communicates with the water outside by a duct which opens at the extremity of the joint under a fringe of setæ.

Second antennæ (Pl. XXIV. fig. 5).—The peduncle consists of four (perhaps five) joints, and bears a long flexible flagellum; all the joints are more or less flattened out laterally, but the upperside of the first and second joints is produced into a longitudinal crest or ridge, which gives the base a somewhat triangular section. The first and second joints are short and subequal in length; both bear on their outer extremities a crown of short spines, and the second joint has also a tuft of fine setæ on its inner extremity. This joint also bears an oval plate (the scaphocerite of Spence Bate) fringed with long plumose setæ.

This appendage has a uniformly smooth margin, but it is slightly raised into a median ridge, especially in its basal portion. The third joint, which is subequal with and nearly covered by the scaphocerite, is slightly longer than broad, flattened and thickened on each margin, where it bears a fringe of plumose setæ, those on the inside being the longest. The fourth joint is shorter and narrower than the third, and is also similarly furnished with plumose setæ; at its extremity it bears a very short joint, which, though somewhat narrower than the one bearing it, is considerably broader than the joint of the flagellum which succeeds it. It is probably the fifth joint of the peduncle which is thus almost merged in the fourth.

The flagellum is not quite two-thirds as long as the body of the animal, and is composed of very numerous (45 to 60) joints. Each joint bears at its extremity on both sides a number of setæ, those at the proximal end being long and plumose, but diminishing in size and becoming smooth on the more remote joints; the last joint is blunt and bears numerous short simple setæ.

The *oral aperture* (Pl. XXV. fig. 10) as seen from below is well defined. The *upper lip* is a thick fleshy appendage, rounded in front and widening out below. It seems to have very considerable flexibility and power of movement, and is strongly supplied with muscular bands. Close behind it lie the cutting-edges of the *mandibles* (Pl. XXIV. figs. 10, 11, and 12), which are similar on both sides. These organs are strongly developed, and are so placed as to close the mouth-opening with their exposed side. The cutting-edge is furnished with a double row of strongly indurated teeth, while placed nearly at right angles and interior to it is a ridge fringed with short bristles, culminating in a strongly-produced grinding tubercle with an oval finely-toothed margin. The palp is 3-jointed, and when at rest projects forward between the bases of the first pair of antennæ: the basal joint is broader than long, and furnished with a few short plumose setæ on each side; the second joint is much the longest, is three or four times as long as broad, and bears a tuft of setæ at its upper distal extremity; near its base on the lower side it is produced into a short triangular tooth, while on the distal two-thirds of the same side it bears numerous short setæ arranged in two rows and leaving a long narrow groove, into which apparently the third joint can be folded and so completely protected; the third joint is short, slightly broadened towards the outer end, and densely fringed with short setæ. All the setæ on this organ are furnished with very short hairs, which almost make them appear serrated. The base of the mandible is widely dilated for the reception of the powerful muscles by which it is moved.

The *under-lip* (Pl. XXIV. fig. 9), placed immediately behind the mandibles, is a deeply 2-cleft fleshy plate, rounded on the outer margins, and finely fringed on the upper and inner with minute close-set hairs. The two sides appear to be capable of opening widely apart.

First maxillæ (Pl. XXIV. fig. 6).—These organs are 2-branched; the external branch, which is strongly chitinous, bears on its inner oblique margin a double row of serrated spinose teeth, which are brown-coloured and strongly chitinized; the inner branch is fleshy, smaller, more rounded, fringed with short plumose setæ, and seems to have but little power of movement.

Second maxillæ (Pl. XXIV. figs. 7 and 8).—These are thick, fleshy, and 4-branched, each branch being 1-jointed. The broad basal portion which bears these branches is rounded on its outer edge, which bears a few small spines; at its upper and outer extremity it has a small crown of setæ at the articulation of the outer branch. This basal portion is longitudinally a little bent on itself, so that while the two outer branches on each side work against each other, the two inner lie more in the same plane and move obliquely one against another. The first (outer) branch is short and rounded, and, as is the case with the second branch, ends in a great number of setæ, which are somewhat curved inwards and are toothed along their inner margins. The third branch resembles the narrow second one in form, but the setæ are not toothed. The fourth (innermost) branch is setose along its inner margin, and is expanded on its outer into a thin rounded lamella which partly covers the third branch. These four setose plates are evidently for the purpose of preventing particles of food from escaping from the oral aperture.

Maxillipeds (Pl. XXIV. figs. 13, 14, and 15).—These organs are distinctly pediform, differing from the succeeding pairs of legs only in the degree of their development. They are 7-jointed. The coxal joint bears on its outer side two lamellar branchiæ, each of which is obliquely crossed near its base by a fine line of articulation; the upper of these is more than twice as broad as the lower, which is long and very narrow. On its inner side the coxa bears two small lamellar organs fringed all round with setæ, the inner and narrower of which stands alongside, but at right angles to, the outer. These setose plates serve to close the oral aperture behind. The upper portion of this joint bears at its outer extremity a slender appendage which is subequal in length to the rest of the joint. This exopodite appears at first sight to be unjointed, but is seen to bear a minute articulation at its apex.

The basos is long, and is rounded on the anterior or outer side, while the keeled inner side bears a double row of plumose setæ. The ischium, which is similarly shaped in section, is about half as long, and the meros is as long, as the basos. The two succeeding joints form a distinct—and in spirit-specimens a sharp—geniculation with the meros, being bent in towards the middle line of the body; they are both somewhat shorter than the meros, and are rather densely setose. The propodos is more flattened than the carpos, and is fringed with numerous curved hairs on both margins, while the dactylos ends in three powerful hooked claws, which are almost hidden among setæ.

These organs I have termed maxillipeds, as in position they correspond to those appendages in other Crustacea; but they might more appropriately be called the *first pair of walking legs*.

The next seven pairs of legs resemble the preceding pair in general structure, but differ considerably in detail; they all want the setose lamellæ on the inside of the coxal joint, which indeed appear to act partly as oral organs, but several of them have a small pointed lobe which may be a homologous development. The exopodites and branchiæ are differently developed in all the limbs, while the basal joint is shorter than in the first pair. In the second to the sixth pairs, the long plumose exopodites apparently serve as natatory organs and facilitate progression though the water.

In the *second pair of legs* (Pl. XXIV. fig. 16) the joints are similar in number, shape, and relative length, as well as in distribution of setæ, to those of the first pair. The lamellar branchiæ are, however, much broader and are subequal in size, the lower one being more oval and pointed than the upper. The exopodite is developed into a long peduncular joint, bearing a stout multi-articulate flagellum, fringed on the posterior side of the articulations with long plumose setæ.

The *third pair* closely resemble the preceding, but are in every way larger. The lower of the two branchiæ is slightly larger than the upper.

The *fourth pair of legs* are the longest of all. The lower branchia is half as large again as the upper.

The *fifth pair* are similar to the fourth in most respects, but the setæ are more tufted and scattered. On the coxal plate there projects downward and alongside the basos a small lobe, tufted—especially at the end—with setæ.

The *sixth pair* (Pl. XXV. fig. 1) are shorter, slighter, and less setose than the preceding. The exopodite is, however, relatively strongly developed and is nearly as long as the whole limb, while in the much larger third pair of legs it does not reach the extremity of the meros. The setose lobe on the coxal plate is half as long as the basos.

The *seventh pair* of legs (Pl. XXV. fig. 2) show a sudden diminution in the size of the branchiæ, which are not half so large as in the preceding pair. The exopodite also is reduced to a small branchia-like projection, not reaching the extremity of the ischium and quite destitute of segmentation. The joints of the leg are more slender and the setæ fewer than in the preceding pair, but the coxal appendage—at least in the females—is much more strongly developed.

In the *eighth pair* (Pl. XXV. fig. 3) the diminution is most pronounced; the joints are slender and nearly destitute of setæ, while the branchial plates and exopodite are totally wanting.

The exact relation of the joints of the legs near their point of attachment to the body is somewhat difficult to make out. In the first pair—the maxillipeds—there appear to be eight joints, and if we count back from the dactylos it would seem that the coxal joint is separated into two articulations, the proximal part bearing the branchiæ and the internal processes, and the distal part the exopodite. The same arrangement is seen in the second pair of legs. The eighth pair is also segmented into eight very distinct joints, none of which bear appendages. But in the sixth pair the coxa appears to be reduced to a plate passing on the inner side into the sternum and carrying the branchiæ on its outer side, while the exopodite is borne on a special lobe or process. In the seventh pair the coxa appears to be cleft longitudinally, the inner part bearing the ciliated lobe, while the outer carries the branchiæ and the exopodite. The latter is not on a distinctly separated process, but has a constriction at its base as if indicating a rudimentary joint. The joints of all the eight pairs of legs from the dactylos to the basos appear to be easily homologized; the difficulty of identification seems to lie in the development of the coxa.

In the females *the genital opening* (Pl. XXV. fig. 3) is a transverse slit on the apex of a rounded tubercle which is placed just anterior to the last pair of legs. It stands between, and a little in front of, the coxal joints, and almost on the sternal divisions. The setose processes on the inside of the fifth, sixth, and seventh pairs of legs have probably some relation to this organ.

The five pairs of *pleopoda* (Pl. XXV. fig. 4) on the first to the fifth abdominal segments are all of a similar form in the females. Each consists of a subquadrate basal joint, the outer portion of which appears almost as if articulated on to the rest. Near the outer angle is the large multi-articulate exopodite, which forms an apparently more perfect oar than the corresponding organ on the thoracic legs. Each is formed of numerous short joints carrying several long plumose setæ. On the inner side of the base is a small oblong plate like a rudimentary branchia—the endopodite. In going back from the first to the fifth segment, this endopodite diminishes in size.

In the males the first pair of pleopoda (Pl. XXV. fig. 5) have the exopodite normal, but the endopodite developed into a lamelliform plate which projects inward (figs. 6 and 6 *a*). This plate appears to be furnished with a duct which opens near its extremity. The whole organ is somewhat dilated toward the end, and is furnished with a row of minute spines down the sides of the duct. In the second pair (Pl. XXV. fig. 7, 8, and 9) the endopodites are each produced into an elongated peduncle, which is deeply grooved on its inner face, and bears a double row of stout, slightly-curved spines near its extremity, and a scoop-like terminal process having smooth edges and with the hollow faces meeting in the middle line. Both pairs evidently act as copulatory organs; but I have not been able to trace the passage of the vasa deferentia into the first pair, which I think represent the openings of the male generative organs. The second pair appear to act only as clasping-organs. The succeeding 3rd–5th pairs of pleopoda are similar to the corresponding limbs in the females.

The *uropoda* form with the *telson* a large tail-fin (Pl. XXV. fig. 9), as in most shrimps. In each the basal portion is relatively small, while the exopodites and endopodites are produced into large plates or swimmerets; these are subequal in length, oblong in form, and bluntly pointed: the distal halves of all four plates are densely fringed with long comb-like setæ or spines; the proximal halves of the inner plates are quite smooth on the outer margin, while those of the outer plates have a very few short spines.

The *telson* is short and almost transversely truncate, its length hardly exceeding the breadth at its base. The blunted end is furnished with a fringe of comb-like teeth. The shortness of this telson is a characteristic feature, as in the majority of Schizopods it exceeds the uropoda in length. It is only in certain genera of Mysidæ (e. g. *Euchætomera*) that the latter reach far beyond the end of the telson. The relative width of the uropoda in *Anaspides* causes this tail-fin to act as a very powerful swimming-organ, and this enables the animal to retreat very rapidly from any danger menacing it in front.

The largest specimen of *Anaspides* examined by me was 38 mm. or $1\frac{1}{2}$ inch long, but the length in smaller specimens hardly exceeds 25 mm. I found ova in the oviducts.

Anatomical Structure.

I have met with very considerable difficulty in working out the structure of *Anaspides*, owing to the imperfect state of preservation of my specimens. These when caught were merely put into alcohol of unknown strength, and even this was not changed for two or three weeks. The result was that all the internal organs were more or less disintegrated, and it was a matter of difficulty—and in some cases of impossibility—to separate them one from another or from the adjacent tissues.

In not a single specimen could I isolate the heart throughout its length or trace the course of the principal blood-vessels. The same remark applies to the hepatic tubes, which were completely disintegrated except at their extremities. This has necessarily led to an incomplete and imperfect resolution of many details of structure. The best results in regard to the soft parts were obtained by means of sections.

Alimentary system.—The œsophagus is very short and passes vertically into the stomach (Pl. XXVI. figs. 1 and 6). The latter is an open sac, curving over nearly at right angles to the gullet and passing directly back into the intestine; it is of very simple structure as compared with the usual structure of this organ in the higher Crustacea. In front, and just where it widens from the œsophagus, the median line is chitinized into a stout ridge which thickens upward into a club-shaped process, covered at its extremity with fine tooth-like rugosities, and projects into the cavity of the stomach (fig. 7). Above this process the median ridge bends over to form the dorsal ridge of the stomach, and this thickening is continued back as far as the fourth thoracic segment. On each side of the base of this line the chitinous thickening is expanded into a two-lobed process, ending in sharp and somewhat widely separated points. At the posterior side of the mouth-opening there arise two stout chitinous ridges densely covered, especially at their base, with setæ or curved bristles, all pointing inward. Thus the opening of the stomach is guarded by so many projecting processes that it must be almost impossible for food to be again ejected at the gullet. On each side of the frontal median ridge the stomach is produced into two curved concavities occupying the front portion of the cephalic segment almost to the bases of the antennæ and the ocular peduncles. The base of the stomach, reaching back from the œsophagus to near the fourth segment of the body, is chitinized, and the bands on each side of it are thickly ciliated (fig. 8). Two other ciliated bands pass up the sides and converge towards the median band, forming along with it the roof of the cavity. The side-walls of the stomach between the chitinous bands are very thin and membranous, and are protected by the dense mass of muscles of the mandibles. The whole of the stomach and part of the fore-gut appear to be covered by a longitudinal sheath of muscular tissue. Except the club-shaped projection in the front of the stomach, there seems to be no special masticatory apparatus, and trituration of the food appears to depend on the up-and-down movement of the whole upper part of the sac. Maceration of the food is certainly very imperfectly effected, as I have investigated the contents of the intestine and found that so far back as the seventh thoracic segment fragments of Copepoda, &c., occurred, in which the integuments and portions of the limbs were still intact. I think it probable that the hepatic tubes open into the alimentary canal just at the posterior end of the stomach or at the very commencement of the intestine; but neither by dissection nor by longitudinal and transverse sections could I detect the opening, although the tubes themselves were in several cases followed up to this part of the canal.

From the stomach the intestine proceeds back as a straight, simple, and rather wide tube; for about the posterior half of its length the wall is wrinkled into small folds, as if capable of very considerable backward and forward movement. At about two-thirds of its length, or just about the first abdominal segment, it bears on its upper surface a short oval cæcum—in large specimens about 2 mm. long,—directed forward (Pl. III. fig. 2). This organ is evidently an excretory gland. Its cavity is densely lined with tube-shaped cells placed vertically to the walls, leaving a hollow space in the interior, which is partly filled with loosely-interwoven elongated and pointed cells, and communicates by means of a short duct with the intestine. At about the extremity of the antepenultimate segment of the abdomen the intestine bears on its upper surface another cæcum, shorter than the first and directed backward (fig. 3). This is also lined with glandular tissue arranged in the same manner as in the anterior one, and has a central duct. The function of both these organs is probably urinary. In the last abdominal segment the intestine contracts sharply to less than half its previous diameter, and, entering the telson, bends abruptly upward and backward, and then passes out nearly straight to the anus, which is in the form of a longitudinal slit. Where it contracts the wall is surrounded by a coat of muscles arranged in an annular manner.

The *liver* is quite different in its structure from the corresponding organ in any other Crustacean with which I am acquainted. Owing to the very soft tissue of which it is composed, especially in its anterior portion, and its consequent state of disintegration in all my specimens, I have been able to make out only a portion of its structure. It consists of a number of slender cylindrical tubes, lying horizontally, but slightly interwoven in the body-cavity, above and on both sides of the alimentary canal, and reaching back to halfway between the intestinal cæca. In one specimen I traced as many as eighteen of these tubes forward to about the posterior end of the stomach, but failed in every instance to find any duct or opening into the alimentary canal. These tubes are of a yellowish straw-colour in ordinary spirit-specimens. Their posterior portions, when considerably magnified, exhibit at the extremity a mass of slightly elongated pointed cells, thickly charged with granular contents (Pl. XXVI. fig. 9). At a short distance from the end a duct arises, the cells all round it, which line the walls of the tube, being arranged in a more or less vertical direction.

Excretory organs.—My identification of the so-called "green gland" or renal organ characteristic of all the higher Crustacea is not satisfactory, if indeed it exists at all. I have not identified it in dissected specimens, but in one or two sections I have observed what appears to be a small mass of glandular tissue lying in front of and partly below the anterior lobes of the stomach and close up to the bases of the lower antennæ. At the same time I have not found any duct by which its excretions are liberated. It is just possible that I have mistaken for this the somewhat disintegrated tissue of the preoral ganglion; but if so, its connexion with the large nerves supplying the eyes has not been traced. It is perfectly possible that the organ is wanting or only exists in a rudimentary state, especially if the intestinal cæca usurp its functions, as I have surmised.

Circulatory apparatus.—My observations on this part of the anatomy are very fragmentary, but they are sufficient to attest the primitive character of *Anaspides.*

The *heart* consists of a long simple tube, apparently little dilated in each body-segment, lying close to the dorsal surface and tapering gradually at both ends into a more slender cylindrical vessel. I have traced the whole tube from about the third thoracic segment back past the posterior intestinal caecum. Of the arteries passing from the heart, exclusive of its anterior and posterior prolongations, which may be considered respectively as the cephalic and upper abdominal arteries, I have succeeded in tracing only one prominent artery passing almost vertically downward between the seventh and eighth thoracic segments, which probably supplies the greater portion of the sternal region. But I have failed to find any trace of the valvular openings into the pericardial sinus, by which the blood returning from the branchiæ and other portions of the body is again fed back to the heart. This is of course due to the very imperfect condition of the tissues examined.

The branchiæ, as already mentioned, are all lamelliform and are carried externally. Morphologically there are seven pairs on each side, but those of the first pair of legs (maxillipeds) are very much reduced in size, and probably more or less in function also. The branchia-like endopodites of the abdominal appendages are no doubt functionless as breathing-organs.

Reproductive organs.—I have not succeeded in definitely making out the structure of the testes and vasa deferentia in the very few male specimens at my disposal. The male organ, so far as it was identified, consists of two thin, whitish tubes, lying nearly parallel one to another, above and slightly on each side of the intestine (Pl. XXVI. fig. 5). These extend from the third segment of the thorax, where they are smaller and very much twisted, as far back as the telson. The densely-twisted part of the organ lies in the penultimate segment of the thorax. The vasa deferentia pass outward from the body-cavity by two rather wide tubes, which come down near the outer side of the body to the first pair of abdominal legs.

The ovaries form a somewhat flattened pinkish mass on each side of the body above the alimentary canal, having rounded lobes projecting upward and downward so as almost to meet in the median line. The supra-abdominal artery lies along the margins of these lobes, which extend from the last segment of the thorax to the region of the posterior intestinal caecum. In more sexually mature specimens in which the ova were found lying in the oviducts, the latter were seen to lie lower down in the body-cavity, at the sides or even below the intestine. In the most advanced specimen examined the ova were nearly one millimetre long and were oblong in form. Even in such relatively well-developed ova there was no commencement of differentiation into definite structures. The whole interior appeared to be composed of more or less spherical cells, which were especially densely packed and were smaller in size towards the centre. Even at this stage, the ovum had a strong, homogeneous, well-defined wall, and appeared as if nearly ready to be extruded. In one specimen I found ova ranging from an early morula (?) stage up to the form described, but all the tissues were in bad preservation. I have not succeeded in tracing the ovaries down to the genital opening, which is on the sternum, between the last two pairs of thoracic legs.

Nervous System and Sense-Organs.

The *nerve cord* (Pl. XXVI. fig. 4) was easily traced along the whole ventral surface of the body from the extremity of the abdomen to the mouth, but the organization of its anterior end was not made out satisfactorily either by dissection or by means of sections.

In the abdomen there are six quite distinct paired ganglia, the cords being almost united at the very base of the telson to form the largest of these. From each pair of ganglia at its anterior and outer side there proceeds a dense plexus of nerves to the surrounding masses of muscular tissue, while from its posterior outer side there passes one rather stout nerve obliquely backwards and downwards to enter the appendage. Each pair of ganglia is separated by two very distinct and somewhat widely separated commissures.

In the thorax the ganglia lie much closer together, the commissures, though quite distinct, being parallel and touching throughout their length. The ganglionic portion of the cord is not sharply defined as in the abdomen, the position of the different centres being made out most readily by the nerves which pass into the appendages. There appear to be seven (or eight) fairly well-defined ganglia in the thorax, but immediately behind the gullet is a mass of ganglionic tissue which appears to supply all the mouth-organs, but which I was not able to resolve into its constituent elements; nor could I trace the passage of the commissures round the mouth to the anterior ganglionic mass from which proceed the powerful nerves which supply the eyes and the antennæ.

The *eyes* are well-developed as in the higher forms of Crustacea. I have not examined their minute structure.

The *organ of hearing* (Pl. XXVI. fig. 10) is situated in the basal joint of the first pair of antennæ. It consists of an oblong cavity, occupying about two-thirds of the length of the joint, and communicating with the outside by a duct which opens at the end of the joint under a tuft of terminal setæ. The roof of the cavity is formed by the flattened upper surface of the joint. This roof is lined by a colourless tissue formed of two (or three?) layers of somewhat elongated hyaline cells, standing obliquely or nearly vertically to the surface. The internal layer which forms the lining of the upper part of the cavity appears to form a series of trumpet- or cup-shaped sockets, into which the auditory hairs are jointed. Each of these hairs consists of a club-shaped stalk or pedicel, bearing an elongated bell-shaped cell or capsule (fig. 11). I cannot make out without fresh material whether these cells are open or not; I am inclined to think that they are closed sacs. I have not been able to trace the separate nerve-fibres passing into these auditory tubes, except near their base, but a very considerable nerve enters the antenna, and has been followed by me nearly up to the auditory cavity.

I could not detect any trace of sand-particles such as are common in most of the higher Crustacea, in which the auditory sac communicates with the outside water by a canal, nor of an otolith such as occurs in those forms which have a closed sac. Each auditory tube or hair appears to possess a somewhat complicated structure in its capsular portion. These sense-organs are quite unlike any others hitherto recorded among the

Arthropoda, and will evidently repay close investigation. I think each cavity contains a single row of these auditory hairs.

I have already referred to the tactile and olfactory hairs of the antennæ.

Fragmentary and imperfect as this sketch of the anatomy is, it is sufficient to show that in several respects the structure of *Anaspides* is unique among Crustacea. The abdominal cæca, the numerous isolated hepatic tubes, the simple tube-like heart, and the curious structure of the auditory hairs are features peculiar to this Crustacean, differentiating it not only from other members of the family Schizopoda (from which *Anaspides* is also separated by its want of a carapace and external lamellate gills), but, I think, from all other described Malacostraca.

Affinities and Systematic Position.

Anaspides is manifestly a schizopod shrimp, but its greatly generalized characters as well as its remarkable habitat point it out as a survival of a very old type. The most conspicuous external features are the want of a carapace and the plate-like character of the branchiæ. Both are no doubt associated with its habitat among the clefts of rocky pools, where its enemies were probably few and far between, and in which its body was greatly protected, but the former feature especially seems to me indicative of the great antiquity of the type. Until the full development has been worked out—and we know absolutely nothing about it yet—it is impossible to arrive at any conclusions as to how far the carapace is developed in the embryonic stages; but, with this solitary exception, I know of no Crustacean belonging to the Thoracostraca in which there is absolutely no trace of a carapace in the adult forms.

In general appearance *Anaspides* approaches nearest among Schizopoda to the family Euphausiidæ, with which it agrees in the following external features:—(1) the 7-jointed pediform maxillipeds; (2) the general uniform structure of the walking-legs; and (3) the well-developed natatory abdominal limbs, the first two pairs of which are modified in the males as copulative organs. The points of dissimilarity are numerous enough, but they are features in which it differs from all Schizopods, and not from the Euphausiidæ alone. Sars has shown * that in the Euphausiidæ there are six principal stages of development. After the young animal has passed through the *Nauplius* and *Metanauplius* stages, it enters on the *Calyptopis* stage, so-called by him after one of Dana's spurious genera. In this stage, in which only the cephalic appendages are present, the carapace is attached to the anterior part of the body of the larva, and though it projects backward to cover the portion which afterwards develops into the thoracic segments, it is not anywhere joined to these segments, but only to the cephalon. Even at this early stage, however, it covers and comes to be attached to the somite which bears the maxillipeds. Thus early in the development of a typical Schizopod has the carapace come to be a prominent feature. It may here be pointed out that the resemblance of the body of *Anaspides* to that of a sessile-eyed Crustacean is not confined to the want of a carapace and the occurrence of lamellate branchiæ; it is also suggested

* Report on the Schizopoda of the 'Challenger' Expedition, p. 150.

by the presence of a well-marked lateral suture on the first thoracic segment, recalling the epimeron of most Isopoda, which, however, is in some instances not developed on the first, though prominent on the succeeding segments.

The plate-like character of the branchiæ is a feature which does not exhibit nearly so radical a digression as the loss of the carapace. In the development of *Euphausia pellucida,* Sars has shown * that after the *Calyptopis* stage the larva passes through a *Furcilia* stage, in which the anterior legs and the pleopoda begin to develop. The legs first appear as simple processes or lobes, giving rise on their outer side to a minute knob, which is the rudimentary exopodite. As the endopodite develops and gradually becomes articulated, a simple knob-like protuberance arises at its base, below the exopodite, which as development proceeds bifurcates into two rudimentary plates. This stage appears to correspond with that reached by *Anaspides*, only in the *Furcilia* larva the branchiæ continue to subdivide until they ultimately become arborescent in the adult, because they are sheltered under a carapace and so must expose the largest surface possible to the somewhat limited supply of water with which they are surrounded. In most of the Schizopoda the gills become arborescent.

The archaic character of *Anaspides* is more fully revealed by a study of its anatomy. The alimentary canal shows a much simpler structure than prevails in any other described Schizopod. In *Mysis* †, which may be looked on as one of the least highly developed forms of the suborder, the stomach is distinctly divided into an anterior (cardiac) and a posterior (pyloric) portion; the latter is much the smaller, is of very complicated structure, and is the part in which the food is chiefly triturated. Opening just behind it and placed dorsally is a small cæcum, which acts probably as a sort of salivary gland. The liver is composed of ten pouch-like masses, five on each side, which unite their contents into a hepatic duct entering the intestine just where it leaves the stomach. The intestine is a nearly straight tube, passing directly to the anus, and having no cæca or diverticula communicating with it anywhere behind the opening of the hepatic duct. In *Euphausia* ‡ the structure of the alimentary canal is essentially similar, but above the pyloric portion of the stomach are two small incurving cæca (not one as in *Mysis*), while the liver consists of a mass of minute hepatic tubes on each side of the intestine and not reaching to the posterior portion of the thorax. These masses of tubes are quite distinct in appearance and aggregation from the long isolated tubes of *Anaspides*. Cæca of the mid-gut are found in all orders of Crustacea as paired or unpaired organs. Their position appears to vary a good deal. For example, in some Brachyura (e. g. *Carcinus*) a pyloric cæcum or diverticulum arises on each side of the stomach in front of the hepatic ducts, which when uncoiled exceeds the intestine in length, while at about one-third of the distance from the stomach to the anus a solitary cæcal appendage arises, also in the form of a long tube. In others (e. g. *Maia*) the latter cæcum is placed at the extreme anterior extremity of the intestine. In the Macroura there is always the usual pyloric cæcum, but in some genera (e. g. *Astacus*)

* *L. c.* p. 163, pl. xxx. figs. 23–27.

† G. O. Sars, 'Hist. Nat. des Crustacés d'eau douce de Norvège,' p. 26.

‡ 'Challenger' Report, p. 73.

there is no appendage of the intestine, though this is present in others. In all the Thoracostraca the liver is in the form of a more or less compact mass composed of numerous small cæca. In Amphipoda (e. g. *Gammarus* *) a single pyloric cæcum opens just behind the stomach, and this is also probably salivary in its function; while at the posterior end of the mid-gut two slender cylindrical processes open into the intestine. These cæca are placed along the dorsal surface of the intestine, and reach as far forward as the last thoracic segment. Their function is probably urinary. In *Caprella dentata* † a single pyloric cæcum is placed dorsally to the posterior part of the stomach and opens in the front part of the intestine, while near its posterior extremity the intestine carries a small simple cæcum very similar to the posterior one in *Anaspides*.

In the Schizopod under consideration the stomach is hardly separable into a cardiac and pyloric portion, nor is the separation between the hind part of the stomach and the intestine at all well marked. The liver is unique in its structure. There is no trace of a pyloric cæcum ‡, the first organ of the kind being placed as far back as the first abdominal segment. From the imperfectly triturated condition of the food in the part of the intestine which passes through the thorax, I am inclined to believe, as said before, that the gastric function is only imperfectly performed by the stomach, and that the anterior part of the intestine acts as part of the pyloric stomach. If this be so, the anterior cæcum may still function partly as a salivary organ (though this is hardly probable), and the posterior one, which is placed far back in the alimentary canal, may be excretory only and may act as a urinary gland. It is clear, however, that the whole structure of the alimentary canal bears a closer resemblance to the lower Amphipoda (Caprellidæ) than to any of the higher forms of Crustacea, and this is probably to be looked on as another survival of a primitive type of structure.

The circulatory apparatus has been shown to be very elementary in its structure. In the Brachyura the heart reaches its maximum development, occurring in most crabs as a short polygonal vessel placed in such a central position as to readily control by its rhythmic action the blood-supply of the body. In Macroura it is also a well-developed saccular organ, from which the passage of the various arteries can readily be traced. In Schizopods, though not so well developed, it still preserves its saccular character. But in *Anaspides* it is apparently reduced to a simple tube. Only in the Stomatopoda, among the higher Crustacea, is there any approach to such a primitive form.

It is premature, with the imperfect knowledge of this animal still at our disposal and our absolute ignorance of its development, to attempt to frame any genealogical scheme showing its position among the Schizopoda, but from the points referred to I think it probable that the Anaspidæ and the Euphausiidæ were somewhat closely allied in their origin.

* Sars, Crustacés d'eau douce, p. 55.

† P. Mayer, 'Die Caprelliden des Golfes von Neapel,' p. 147, Taf. 9. figs. 2, 3, and 4.

‡ This statement must be accepted with the reservation due to the fact that I could not make out this feature clearly, but it appeared to me as if the upper part of the pyloric portion of the stomach was enveloped in an easily disintegrated tissue of which I could not trace the close connection with the alimentary canal which certainly existed. Whether this tissue represents an imperfectly developed pyloric cæcum, or an anterior process of the liver, I have not succeeded in demonstrating.

In trying to arrive at some conclusions as to the length of time during which *Anaspides* has been isolated, the following facts are of interest. I am indebted for this information on the geology of the district to my friend and former pupil, Mr. A. Montgomery, M.A., Government Geologist of Tasmania. The top of Mt. Wellington, as well as the central plateau of Tasmania, consists of a mass of greenstone (diabase) of about Permo-Carboniferous age. According to Mr. R. M. Johnston, the greenstone existed prior to the deposition of the shell-beds and sandstones which flank its base, while Messrs. Stephens and Montgomery consider it to be younger. Mr. Johnston admits, however, that there was a "newer greenstone" eruption which broke through these marine deposits, so that it is agreed that the Permo-Carboniferous beds were penetrated by greenstones subsequent to their formation, and it is probable that the eruption of these greenstones and the elevation of the marine beds were contemporaneous. The greenstones break through and cover the Upper Coal-measures, which have been referred to the Mesozoic period on account of the plant-fossils contained in them, though no stratigraphical break has yet been discovered between them and the Permo-Carboniferous marine beds at a horizon very little below them. If Mesozoic at all, they must probably be referred to the beginning of that period, and the greenstone eruptions were probably little later. They were certainly older than the oldest Tertiary beds, which may be Eocene. There are no Secondary marine beds, and the Tertiaries are quite littoral, so it appears certain that Tasmania has never been under water to any great extent since some time in the Mesozoic, and possibly since the close of the Palæozoic period. It seems probable that the basaltic eruption, of which the diabase greenstones are the remains, took place early in the Mesozoic period, and that it was of immense extent, the whole of the eastern half of the island being covered with lavas. Sub-aerial erosion has since carved out these, leaving the central plateau and the top of Ben Lomond as remains of the great covering sheet, and exposing the dykes and bosses through which the molten matter was ejected, in the numerous small greenstone hills in the lower country. Mt. Wellington was probably one of the large centres of eruption, as a deep bore at the Cascades near Hobart shows the greenstone to underlie the Permo-Carboniferous beds. The fact that Tasmania has been dry land since Mesozoic times will probably not be disputed by any one conversant with the geology of the country.

It seems to me probable that *Anaspides* has been isolated from some marine form since a period shortly after the eruption of the greenstones referred to. The occurrence of freshwater Crustacea belonging to marine types may be variously accounted for. It is always possible that the animals themselves or their eggs may have been carried by aquatic birds; but I know of no recorded case of such a mode of distribution, nor do I know of any marine form which would survive in fresh water. I have often plunged various littoral species belonging to different families (*Palinurus*, *Atylus*, *Dexamine*, *Sphæroma*, &c.) into fresh water and found that they died in a very short period of time, usually in the course of a few minutes. On the other hand, the adaptability of various marine Crustacea to a freshwater habitat by gradual stages is a well-ascertained fact. The following examples are of interest. In New Zealand I originally described *Idotea lacustris* from brackish water at the mouth of a lagoon which communicates with the sea at spring tides or after heavy rains, and afterwards found the same species further up the lagoon where the water was quite fresh. My co-worker and friend, Dr. Chilton, has since found the species in a mountain stream in the same neighbourhood at an elevation of 1200 feet. It is clear that in this instance this Isopod has within very recent times made its way up the stream, where it is now thoroughly established. The same species has been taken in the Straits of Magellan, and all the other numerous species of the genus and family are marine with the exception of the Scandinavian *Glyptonotus entomon*.

Leander fluviatilis, *Hymenosoma lacustris*, and *Calliopius fluviatilis* occur in New Zealand streams and lakes, and, though not found in the sea, are not uncommon in tidal waters. *Crangonyx compactus*, *Calliopius subterraneus*, and *Gammarus fragilis*, found by Dr. Chilton in the subterranean waters of Canterbury, and *Pherusa cærulea*, found by myself in a stream in the Old Man Range in Otago at an elevation of 3000 feet, are species belonging to marine genera, which have most probably migrated from the sea by gradual stages. I have myself taken *Corophium excavatum*, *Allorchestes recens*, and a species of Schizopod which I identify as *Mysidopsis incisa*, Sars (originally described from a specimen obtained at the entrance of Port Phillip from a depth of 33 fathoms), from the mouths of streams or lagoons where the water is frequently quite fresh. These are a few examples, taken from instances occurring in New Zealand, of a gradual transition of marine into freshwater species, and of which similar examples could no doubt be recorded from all other parts of the world.

In such a manner most probably the ancestral forms of *Anaspides* found their way from the sea in Mesozoic times into the streams and lakes then occurring in Tasmania, in which, to judge from its remarkable specialization, it has been isolated for a great period of time. Its association with *Phreatoicus australis* and *Niphargus montanus* points in the same direction. The former, as already stated, is an Isopod of a very old and greatly generalized type. Its occurrence in two such isolated localities as Mt. Kosciusko in New South Wales, a granitic mass of great antiquity, and Mt. Wellington in Tasmania, and at a very considerable elevation in both, would appear to show that it has survived through long periods of time; coupled with which is the fact of the only allied species being an eyeless form from the underground waters of Canterbury in the South Island of New Zealand.

The very vegetation on the summit of Mt. Wellington suggests the antiquity of the region. Surrounding the locality in which *Anaspides* was found grow numerous forms of plant-life characteristic of the Antarctic Flora of Tasmania, the Australian Alps, and New Zealand, such as *Abrotanella*, *Donatia*, *Carpha*, *Oreobolus*, *Uncinia*, &c., so that could one shut one's eyes to the Australian element which is so abundantly present, it would not be difficult to imagine one's self on a mountain in the south portion of New Zealand or on one of the peaty swamps of Stewart Island.

These facts certainly give no direct testimony to the age of *Anaspides*, but they are suggestive, and may enable us, when its development has been worked out and its own distribution and that of its associated forms are better known, to arrive at some more definite conclusions on the subject.

EXPLANATION OF THE PLATES.

Plate XXIV.

Figs. 1–16. *Anaspides tasmaniæ.*

1. Body of animal, ♀. × 4.
2. Dorsal view of cephalon : (*a*) 1st antennæ; (*b*) 2nd antennæ. × 20.
3. Basal portion of 1st antenna. × 26.
4. Portion of the external flagellum of same, showing setæ and sensory hairs. × 56.
5. Basal portion of 2nd antenna. × 26.
6. First maxilla. × 26.
7. Second maxilla. × 26.
8. One of the comb-like setæ from the outer lobe of the second maxilla. × 56.
9. Under-lip. × 26.
10. Mandible, with palp. × 26.
11. Cutting-edge of same, showing the double row of teeth. × 84.
12. Grinding tubercle of same. × 84.
13. Leg of the 1st pair (maxilliped). × 13.
14. Section of basis of same. × 26.
15. Extremity of propodos, and dactylos of same, underside. × 56.
16. Leg of the 2nd pair. × 13.

Plate XXV.

Figs. 1–10. *Anaspides tasmaniæ.*

1. Leg of the 6th pair. × 13.
2. Leg of the 7th pair, female. × 13.
3. Leg of the 8th pair, female : *g.o.* = tubercle with genital opening. × 13.
4. Second pleopod, female. × 13.
5. First pleopod, male. × 13.
6. Endopodite of same. × 26.

6*a*. Endopodite of same, seen from the inside, young male. × 56.

7. Second pair of pleopoda in male, without the exopodites. × 13.
8. Endopodite of 2nd pleopod in male. × 26.

8*a*. Extremity of same turned inward. × 26.

9. Telson and uropods from above. × 13.
10. Oral aperture seen from the underside. × 10.

i.a., 1st antennæ; *o.a.*, 2nd antennæ; *u.l.*, under lip or metastoma; *man.*, mandibles; *mp.*, maxillipeds.

Plate XXVI.

Figs. 1–12. *Anaspides tasmaniæ.*—Anatomy.

1. Longitudinal (diagrammatic) section through the body of a female specimen (the heart is represented as too near the dorsal surface, the large dorsal muscles not being shown): *o.a.*, mouth-orifice; *in.*, intestine; *h.t.*, liver; *n.c.*, nerve-cord; *c.*, heart; *ov.*, ovaries; *co.*, anterior intestinal cæcum; $co._2$, posterior intestinal cæcum; *an.*, anus.

Fig. 2. Longitudinal section through portion of intestine and anterior cæcum.
3. Corresponding section through intestine and posterior cæcum.
4. Nerve-cord.
5. Testes and vasa deferentia.
6. Outline representing longitudinal section of stomach: *œ.*, gullet; *in.*, intestine.
7. Club-shaped process in front of stomach.
8. Chitinous hairs from the lining of the stomach. Highly magnified.
9. Posterior extremity of a hepatic tube. Highly magnified.
10. Section through base of first antenna showing the auditory cavity.
11. Auditory capsules or setæ. Highly magnified.
12. Basal joints of inner flagellum of first antennæ, showing the remarkable tactile hairs, &c.